NASA Contractor Report 167894

APPLICATION OF PHOTOVOLTAIC ELECTRIC POWER TO THE RURAL EDUCATION/COMMUNICATION NEEDS OF DEVELOPING COUNTRIES

Anil Cabraal and David Delansanta

DHR, Incorporated
Washington, D.C.

and

George Burrill

ARD, Incorporated
Burlington, Vermont

July 1982

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract DEN3-248

Work performed for

U.S. Agency for International Development
Bureau for Science and Technology
Office of Energy

Table of Contents

ORIGINAL PAGE IS
OF POOR QUALITY

1.0 INTRODUCTION

1.1 Background

This study was performed by DHR, Incorporated, and its subcontractor, Associates in Rural Development (ARD), Incorporated, for the National Aeronautics and Space Administration (NASA) Lewis Research (LeRC) Center. NASA LeRC is managing the Photovoltaic Technology Project sponsored by the United States Agency for International Development (US AID). The overall objective of this project is to determine the suitability (i.e., cost competitiveness and reliability) of photovoltaic (PV) power systems for rural applications in developing countries. Potential application sectors include health delivery, education and communication where small amounts of electricity are needed to meet critical needs. The purpose of this study was to identify, examine and evaluate the potential use in developing countries of photovoltaic systems in rural education/communications facilities.

1.2 Objectives

The key area of focus of this report is on existing and planned US AID projects in primary, secondary, and tertiary education, vocational education, general communication and community services, health and nutrition, as well as audiovisual, radio, television, and training equipment uses. A secondary focus is on non-US AID education projects sponsored by the World Bank, United Nations Educational, Scientific and Cultural Organization (UNESCO), and others. Both traditional and innovative education projects were examined. Accordingly, the objectives of this study were as follows:

- To survey the energy requirements of a variety of rural education and communication processes and projects;
- To identify those education and communication processes and projects which can potentially use photovoltaic (PV) power; and finally,
- To identify possible PV demonstration projects in rural education and communication.

1.3 Approach

Four tasks comprised the scope of work for the project, as follows:

Task 1: Development of a work plan to implement the objectives.

Task 2: Data collection, including a survey of current literature, interviews with officials from US AID, the World Bank, and other donor agencies, and identification of electrical load devices.

Task 3: Identification of potentially economically feasible PV applications categorized by energy consumption.

Task 4: US AID Project identification for possible PV demonstrations.

Data collection and activities under this contract included a sectoral analysis of rural education/communication needs and programs in specific developing countries plus a review of typically used electrically-powered educational teaching aids. These data were then used as a bases for the remaining analytical work in this study.

Based on these data, a general typology was developed and used to classify education projects. The general categories developed were as follows:

- General primary and secondary education,
- Vocational Education,
- Agriculture extension services/education,
- Health and nutrition/family planning
- Leadership and management,
- Literacy, and
- General and program administration.

For purposes of further analysis, each of the above categories were assumed to have an associated generic facility consisting of classrooms, audiovisual equipment, lighting, etc. These facilities are described in detail in Chapter 4 and Appendix A of this report. Summarized, these facilities are called:

- Advanced Facilities - Primary School
- Minimal Facilities - Primary School
- Advanced Facilities - Secondary School
- Minimal Facilities - Secondary School
- Adult Literacy Program
- Vocational Education School
- Mobile Center
- Advanced Facilities - Provincial College
- Minimal Facilities - Provincial College

For each of these generic types, assumptions were made as to the number of classrooms and students, available lighting, refrigeration, and types of audiovisual equipment. Consultation with AID education experts and others confirmed, when possible, the generic configurations developed for this analysis.

The projects were first judged to be candidates for additional analysis according to the following criteria:

- Remoteness (not near electrical grid)
- Visibility
- Insolation
- Relationship to AID's program direction and needs; and
- Value of demonstration/replicability

After applying these criteria, a final list of high profile education projects that are likely candidates for PV demonstration were selected. (See Figures 1.1 and 1.2 for a flow chart of the entire analytical procedure.)

From interviews with experts, load profile data were generated for each facility and financial analysis was performed. These analyses consisted of applying life-cycle costing methodologies developed by DHR. The first, a financial analysis (financial viability test) uses nominal prices for fuel, manintenance, and capital costs. The second, an economic analysis (economic viability test) used world or shadow prices. From this approach those facilities and projects that were not clearly economically viable within the time frame 1981 to 1988 were eliminated.

1.4 Report Organization

Summary data on AID projects and educational equipment are provided in Chapters 2 and 3. Selection of those generic applications that are both technically and economically viable is discussed in detail in Chapter 4. Chapter 5 matches the generic applications in Chapter 4 to the projects discussed in Chapter 2. Those projects that are best suited for PV demonstrations are selected.

ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 1.1

THE ANALYTICAL PROCEDURE FOR THE LOAD PROFILE

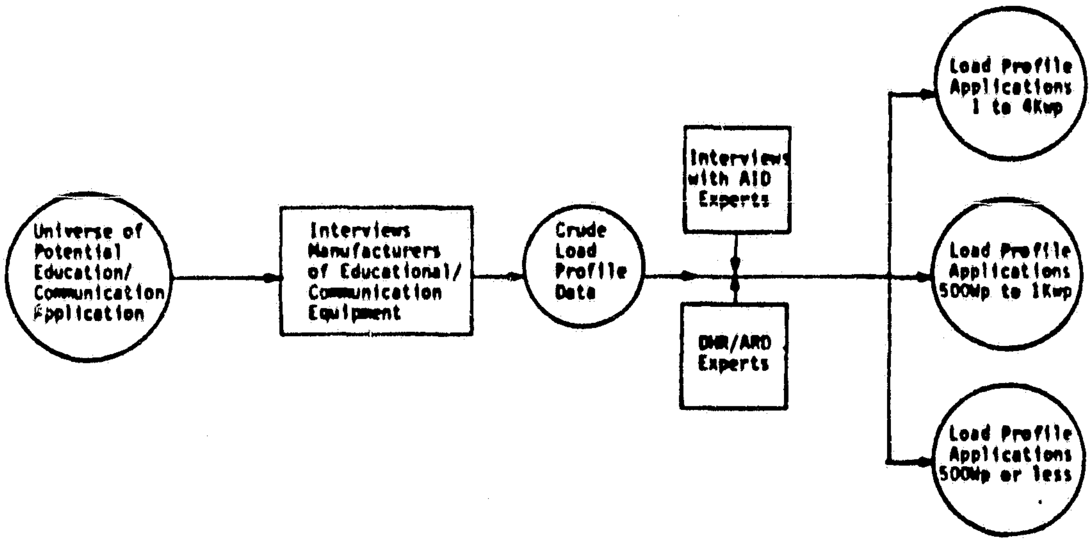
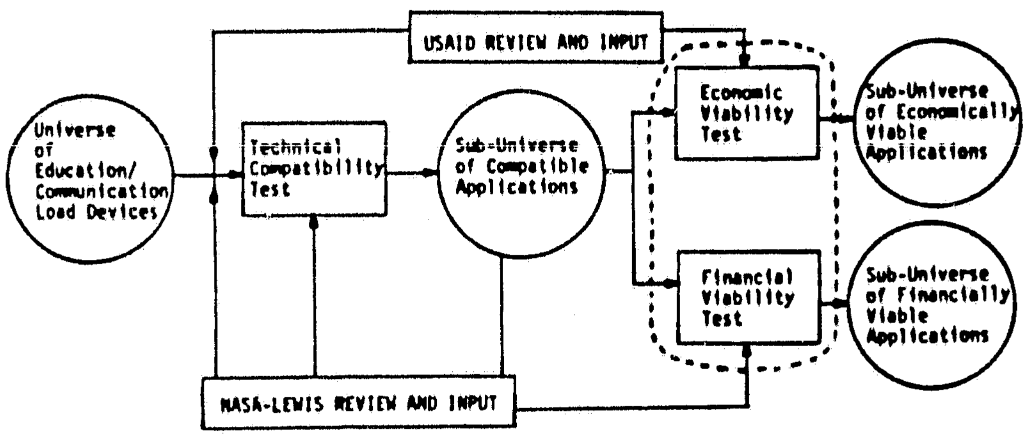


FIGURE 1.2

THE ANALYTICAL PROCEDURE FOR TASK 3



2.0 RURAL EDUCATION PROJECTS IN THE DEVELOPING WORLD

The developing nations, with assistance from donor agencies, such as US AID, the World Bank, and the United Nations, have carried out a broad array of rural education projects over the past decade. These projects address a variety of health, agricultural, population, employment, and management issues. A key purpose of this study was to assemble a descriptive data base on the complete spectrum of these rural education projects. This section summarizes the data base and describes how it was used for the analytical purposes of this study effort.

Besides the functional areas mentioned above, rural education projects also cover a wide range of formal and nonformal education and training activities. Even individual educational projects may have several components supporting different levels and types of education. In addition to general descriptions of project types across this wide range, it has been the further purpose of this study to provide descriptions of the types of most numerous or common projects which utilize electrically-powered equipment . Equipment ranges from instructional technology to the powering of both stationary and mobile facilities for general operations.

Depending upon the local situations and siting (e.g., access to an electrical grid), apparently similar projects may or may not employ electrically-powered equipment. With this constraint in mind, in order to provide both a broad generic overview of rural education projects and to provide a data base organized so that the potential for PV-powered devices could be assessed, the following methodology was utilized.

2.1 Methodology

The approach employed in development of the project data based was effected as follows:

- survey the types of projects now underway and planned at AID and at several of the more active private voluntary organizations (PVOs) and international agencies which have rural education programs;
- develop a typology which reflects the general rural education program types;
- interview AID officials and personnel from other selected agencies as to the usefulness of the typology and as to whether it covered the complete spectrum of projects;
- gather the names and addresses of key organizations; and
- send letters requesting a variety of information on each organization's projects. These letters were followed with telephone conversations or interviews.

Finally, based on responses and upon the study team's assessment of the most active organizations in rural education, a list of organizations was selected for further investigation. Those selected were then extensively contacted by telephone and, in most cases, interviewed in person.

The typology listed below is very similar to that utilized by most international development organizations.

- general primary and secondary education
- vocational education
- agricultural education and extension programs
- health and nutrition and family planning
- leadership and management
- literacy
- general and program administration

In discussions with a number of educational project experts, this typology was confirmed as being very inclusive and also representative of the major types of educational programs.

The organization most fully covered is US AID inasmuch as AID's projects have been the primary focal point of project identification efforts made for this study.

2.2 Background on Key Organizations

In addition to AID, key donor and private voluntary organizations (PVOs) with major education activities in developing countries were investigated to represent the broad spectrum of rural education projects. Through interviews and analysis of project descriptions, the study team assessed the present focus of each organization's educational programming and their near-term direction.

Multidonor organizations surveyed in depth were the World Bank, the Inter-American Development Bank, and the United Nations. Other organizations included Private Agencies Acting Together (PACT), American ORT Federation, Catholic Relief Services, AMIDEAST, World Education, and the Asia Foundation.

The smaller organizations and especially the PVOs were able to supply quite comprehensive lists of educational projects. The larger organizations, and especially the United Nations, were not possessed of an organization-wide list of relevant projects. In many cases, all the information is outside the United States, and information of any detail is only available in the developing country itself. However, as the primary focus of this study is AID, the remainder of this section (2.0) is strictly focused on AID rural education projects.

2.3 AID Rural Education Projects

The AID Congressional presentation for fiscal year 1982 requested $109.6 million for Education and Human Resources Development (EHRD). This amount represents approximately two per cent of the total proposed fiscal year 1982 AID budget. Educational projects that relate primarily to agriculture, nutrition, population planning, and private voluntary organizations are budgeted in separate development categories. This latter point means that substantial efforts in the educational area are categorized by other sectors. Clearly, the overall budget for education activities is substantially higher than $109.6 million.

Although the computerized data bank in AID contains a great deal of agency-wide project information, it is not all inclusive. So, in addition to utilizing this data bank, the study team interviewed regional technical representatives of AID, and numerous knowledgeable individuals in AID, concerning projects related to rural education. As a result of these combined data-gathering efforts, approximately 600 recently completed, ongoing or proposed projects which had some education component were collected, integrated, and reviewed by the study team. Approximately 100 projects were selected for further consideration. They were selected on the following bases:

- to provide both a generic overview of rural education projects; and
- to be inclusive of possible project types where nongrid electically powered devices might be utilized.

A summary of these selected projects is presented in the following matrices (pages 10 through 13), arranged according to the generic project typology listed on page 7. Note that AID's education projects have tended to be concentrated in the general and administration and vocational education fields.

TABLE 2.1

DISTRIBUTION OF AID PROJECTS BY EDUCATION TYPOLOGY AND COUNTRY

SELECTED ONGOING PROJECTS By Country and by Regional and Central Funding	General Primary and Secondary	Vocational Education	Agriculture Extension/Education	Health-Nutrition-Family Planning	Leadership and Management	Literacy	General and Program Administration
Bolivia				1			
Brazil							1
Chad							1
Costa Rica				2			
Dominican Republic	1		1	1			2
Ecuador	2	3					1
Egypt							1
El Salvador	3	1					
Ghana	NO SPECIFIC INFORMATION AVAILABLE						
Guatemala	1				2		
Honduras		1		1	2		
Indonesia					1		3
Ivory Coast	NO SPECIFIC INFORMATION AVAILABLE						
Jamaica	1	1					
Korea	1						
Lesotho							1
Liberia		2					1
Malaysia	NO SPECIFIC INFORMATION AVAILABLE						
Morocco		1					
Nepal					1		

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.1

DISTRIBUTION OF AID PROJECTS BY EDUCATION TYPOLOGY AND COUNTRY

ORIGINAL PAGE IS
OF POOR QUALITY

SELECTED ONGOING PROJECTS By Country and by Regional and Central Funding	General Primary and Secondary	Vocational Education	Agriculture Extension/Education	Health-Nutrition-Family Planning	Leadership and Management	Literacy	General and Program Administration
Nicaragua	1		.	1		1	1
Niger			1			1	
Pakistan				1			1
Palestine	1	1					
	NO	SPECIFIC	INFORMATION			AVAILABLE	
Panama	1	2	1	2			
Paraguay	1	2	1		1	1	2
Peru		2	1	1			3
Portugal	1					1	
Rwanda		1					
Senegal		1					
Syria			1				
Tanzania		1					
Thailand	1	2	1				
Turkey							1
Sudan				1			
Vietnam (South)			1				
Zaire				1			
Zimbabwe	NO	SPECIFIC	INFORMATION			AVAILABLE	

TABLE 2.1

DISTRIBUTION OF AID PROJECTS BY EDUCATION TYPOLOGY AND COUNTRY

SELECTED ONGOING PROJECTS By Country and by Regional and Central Funding	General Primary and Secondary	Vocational Education	Agriculture Extension/Education	Health-Nutrition-Family Planning	Leadership and Management	Literacy	General and Program Administration
Centrally Funded:							
Population and Humanitarian Assist.				1	1		
Technical Assist.	1			1			
Development Support					1		1
Asia Regional					1		
Africa Regional			1				1
Latin America Regional			1	1			
Caribbean Regional				1			
Totals	16	20	11	11	10	4	28

TABLE 2.2

DISTRIBUTION OF FUTURE AID PROJECTS BY EDUCATIONAL TYPOLOGY AND COUNTRY

SELECTED FUTURE PROJECTS	General Primary and Secondary	Vocational Education	Agriculture Extension/Education	Health-Nutrition-Family Planning	Leadership and Management	Literacy	General and Program Administration
Basic Education Development (Yemen Arab Republic)	X						
Village Health Workers Training (Tanzania)				X			
Health Manpower Training (Malawi)				X			
Teacher Training (Swaziland)	X						
Education and Manpower Development (Zimbabwe)		X					
Training for Planning and Eval. of Human Resources Development (Africa Regional)							X
Vocational Skills Development Project (Caribbean Regional)		X					
Development Communications (LAC Regional)							X
Education Sector Program (Nicaragua)	X	X					X
Work Force Development (Panama)		X					
In-Service Teacher Training							X
Non-Formal Education and Unemployed Youth		X					X
Teaching Science by Radio							X
Women in the Labor Force							X
Agriculture and Human Resources Development (Kaedi)			X				X
Southern Sierra Education Sector		X					X
Training for Development					X		X
Management and Technical Skills					X		X
Education and Manpower Development					X		X
Manpower Development			X		X		
Totals	3	6	2	2	4	-	12

2.4 AID Rural Education Projects with Potential for Photovoltaic Applications

Selected projects were reviewed in depth to develop the generic typology of photovoltaic applications (section 4.0). However, for many projects it was difficult to tell from their overview descriptions or from interviews what particular electrically-powered equipment was going to be used, outside of general power for facilities. It is important to note that the DHR/ARD team was instructed by US AID and NASA LeRC at the outset to examine potential applications of photovoltaic power in a general fashion and it is understood that an in-depth project-by-project investigation is beyond the scope of this study.

The matrices on pages 15 through 25 provide a profile of the matches of photovoltaic applications with projects. They have been ranked in terms of the their potential for PV demonstrations, based on these criteria: remoteness, visibility, and relationship to AID's program direction and needs. Inasmuch as the main data source for making these assessments of matches was general overview material and interviews with experts who were unfamiliar with project energy requirements, they are, therefore, subjective. Furthermore, analysis of detailed project documentation for all projects was not possible due to a lack of summary data or unfamiliarity on the part of ARD officials.

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
El Salvador			1			1		El Salvador-Basic & Occupational Skills Trng
El Salvador	2	2						Rural Primary School Expansion
Guatemala	2	2			2			Education & Human Resources Development
Peru			2			2		Vocational Training-Pueblos Jovenes OPG
Liberia			2			2		Liberia-Vocational Training
Liberia						2		Youth On The Job Training
Africa Regional					2	2		Ghana Rural Reconstruction Movement
Technical Assistance								Application of Radio To Teaching of Math
Technical Assistance	3	3						Extension of Rural Primary Schools
Development Support	2	2	2	2	2	2		Rural Satellite Prog-Development Commun

Key: 1-Excellent; 2-Good; 3-Poor, [illegible]

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Dominican Republic			3	3	3			Non-Formal Home Study Second
Ecuador			3	3	3			Education Development-Community Education
Ecuador			3		3			Education Development – Non-Formal
El Salvador	2		2					El Salvador Educational Development
El Salvador	2		2					Education Reform Program
Guatemala	1	1	1		1	1		Primary Schools Improvement
Jamaica	2	2	2	2	2	2		Rural Education Sector Loan
Korea	2	2	2	2				Middle School Pilot Project
Nicaragua	2				2			Rural Education Development
Near East Regional	2	2	2	2	2	2		CRS West Bank-Rural Development II-Education

Key: 1-Excellent; 2-Good; 3-Poor, [illegible]-NA

ORIGINAL PAGE IS OF POOR QUALITY

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Lesotho	2	2	2	2				Instructional Materials Resource Center
Liberia	3	3	3	3	1	2		Rural Information Systems
Nicaragua	3	3	3	3	1	1		Radio Education Eastern Nicaragua
Pakistan	3	3	3	3	1	1		Development Communications Center
Paraguay	1	1			1			Bilingual Education
Peru	1		1			1		Education Service Centers
Turkey								Middle East Technical University

Key: 1-Excellent; 2-Good; 3-Poor; blank-NA

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Peru	2	2	2	2	2	2		Education for Responsible Parenthood
Sudan	2	2	2	2				Rural Health Support
Zaire	2	2	2	2		2		Maternal Child Health/Family Planning
Technical Assistance	3	3	3	3				New Approaches - Mass Media
Population & Humanitarian								Population Field Information Services
Asia Regional								Regional Education Development-Regional Center
Guatemala	1	1	1	1	1	1		Basic Rural Education
Honduras	2	2	2	2	2	2		Civic Development (Leadership Training)
Honduras	2	2				2		Rural Education
Indonesia	1		1		1	1		Educational Communications Development

Key: 1-Excellent; 2-Good; 3-Poor; [illegible]

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Viet Nam (South), Republic								Vietnam-Crop Production
Bolivia							2	Mobile Health Program
Other West Indoes-ECReg.	3		3					Caribbean Family Plan Affiliate PVO-OPG
Costa Rica	2	2	2	2				Nutrition Program
Costa Rica	2	2	2	2				Family Planning Services
Dominican Republic	3	3	1	1				Health/Nutrition Sector Development
Honduras	2	2						Honduras-Nutrition
Nicaragua	2	2	2	2				Nicaragua-Rural Community Health Services
Pakistan	2		2				2	Support of Family Planning Association Activities
Panama	1	1	1	1				Population II (Panama)

Key: 1-Excellent, 2-Good; 3-Poor; blank-NA

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Peru	1	1	1		1		1	Non-Formal Education
Rwanda						3		Farm Hand Tools
Senegal								Integrated Youth Job Development PVO-OPs.
Tanzania	1					1		Vocationalization of Primary Schools
Thailand						2		Vocational Education
Dominican Republic								African Swine Fever Eradication
Niger					1	1		Niamey Department Rural Development
Paraguay						2		Small Farm Technology
Latin America Regional	2	2	2	2	2	2		Rural Communications Services
Syria								Agricultural Education-Livestock Production

Key: 1-Excellent; 2-Good; 3-Poor; Blank-NA

ORIGINAL PAGE IS OF POOR QUALITY

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Panama	2	2	2	2	2	2		Non-Formal Education (Plan Guaymi)
Paraguay	2				2			Rural Radio Education
Portugal			2		2			School Construction
Thailand	2		2		2	2		Rural Education
Ecuador						1		Vocational Education Disadvantaged Youth PVO
Regional Office ROCAP						3		Human Resources Development
Morocco						1		Morocco-Indus Commercial Job Training Women
Panama						2		Education Sector Loan (Phase II)
Paraguay					3	1		Rural Non-Formal Education
Paraguay						1		Vocational Institute (OIS)

Key: 1-Excellent; 2-Good; 3-Poor; blank NA

TABLE 2.3

ONGOING PROJECT AND MATCHING

ONGOING Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Nepal	1	1						Radio Education Teacher Training
Brazil								Scientific Education Publications
Chad	1				1	1		Comprehensive Human Resources Development
Dominican Republic						1		Video-Based Nonformal Education
Egypt								Low Income Housing/Community Upgrading
Technical Assistance								Evaluation of Educational TV Projects
Indonesia								Educational Finance
Indonesia			2	2	2	2		Non-Formal Education
Ivory Coast								Ivory Coast Instr TV Evaluation System
Latin America Regional								Radio Schools

Key: 1-Excellent; 2-Good; 3-Poor; blank-NA

TABLE 2.4

FUTURE PROJECT MATCHING

Future Projects — Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Latin America Regional	3		3		3	3		Development Communications
Nicaragua	1	1	1	1	1	1		Education Sector Program
Centrally Funded	3	3						In-Service Teacher Training
Centrally Funded	2	2	2	2	2			Teaching Science By Radio
Centrally Funded						3		Women in the Labor Force
Peru	1	1	1	1	1	1		Southern Sierra Education Sector
Mauritania			1	1		1		Agriculture & Human Resources Development
Upper Volta								Management & Technical Skills
Ghana	3	3	3	3	3			Population Planning & Rural Development
Ghana								Training For Development

Key: 1-Excellent; 2-Good; 3-Poor; blank-NA

TABLE 2.4

FUTURE PROJECT MATCHING

Future Projects

Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Yemen Arab Republic	2	2	2	2	2	2		Basic Education Development
Swaziland								Teacher Training
Nicaragua	1	1	1	1	1	1		Education Sector Program
Zimbabwe	2		2			2		Education & Manpower Development
Caribbean Regional			1			1		Vocational Skills Development Project
Panama						3		Work Force Development
Centrally Funded			3			3		Non-Formal Education & Unemployed Youth
Tanzania								Village Health Workers Training
Malawi								Health Manpower Training
Africa Regional								Training for Planning & Eval of Human Res

Key: 1-Excellent; 2-Good; 3-Poor; blank-NA

TABLE 2.4

FUTURE PROJECT MATCHING

Future Projects

Country	primary school - improved facilities	primary school - minimal facilities	secondary school - improved facilities	secondary school - minimal facilities	adult literacy program	vocational education	mobile center	Project Title
Ghana						2		Rural Women Outreach
Mali*						3		Integrated Agricultural Ed & Research
Guinea-Bissau*						2		Selected Development Training
Cameroon*	3	3				3		Support to Primary Education

*Projects identified for implementation if additional funds become available. ("Shelf Projects") Not included in generic typology listings.

Key: 1-Excellent; 2-Good; 3-Poor; blank-NA

3.0 Electrical Equipment For Rural Education

A wide spectrum of equipment has been employed in rural education projects over the last decade. Newer models and improved equipment are, naturally, becoming commercially available on a continuous basis. For this study, typical equipment used in rural education projects in the developing world was identified including characteristics of electrically-powered appliances and other load devices. This information was then utilized in this study as a data base to provide part of the economic and technical information required to determine potential PV applications in rural education projects, as discussed in section 4.0. The methodology used and the general content of the information collected are both outlined below.

In order to generate the necessary, and most appropriate, list of equipment. along with information on that equipment, several approaches were employed. First, information on appropriate electrical equipment was elicited from organizations who are currently involved in rural education projects.

Then, interviews with professional educators and specialists in electrical power equipment for education projects were carried out, and publications discussing potential technologies were reviewed. Thereupon, from this information and the types of equipment to be examined, a list of product manufacturers was generated and a letter was sent to them requesting product information.

Following receipt of this information, the products were screened through the selection criteria, some of which are listed below:

- appropriateness of equipment to local education goals;
- reliability of equipment for local environment;
- power requirements in watts, including starting, running, recharging requirements, and time of usage;
- ease operation;
- ease of maintenance and repair;
- availability of spare parts (e.g., light bulbs);
- cost of equipment; and
- weight of equipment.

To the extent possible, equipment rated as the best in each equipment type was then selected. Because some manufacturers did not respond to requests for information, some particular models were not examined. However, in all types of equipment, major suppliers were used, and the equipment is typical of each equipment type.

For analytical purposes, a generic typology of all potential load devices was developed. The typology is divided into seven distinct categories, each relating to the function of the equipment. The first four related to equipment used in the classroom as instructional aids. The remaining categories are to be used for school administration or are to be fixtures in the school.

- audio equipment
- visual equipment
- scientific equipment
- vocational education equipment
- education administration equipment
- communication equipment
- lighting

In summary, the equipment investigated represents generic examples of educational aids which can be utilized in remote rural education and be powered by photovoltaic cells. The power consumption varies from 10 to 15 watts for smaller projectors to 1,200 to 1,500 watts for administrative and vocational equipment. In each case, power consumption and durability were examined to provide quality equipment which was electrically efficient. The needs of educational equipment vary greatly; therefore, a wide spectrum of equipment was examined, rather than just comparing similar equipment. Equipment which was capable of operating on direct current (DC) was selected, when possible. However, in many cases, the larger equipment requires 120 VAC and therefore will require a synchronous inverter. In all cases, equipment was chosen based on what was considered most appropriate for the developing world.

4.0 CHARACTERIZATION OF GENERIC PHOTOVOLTAIC APPLICATIONS

Previous discussions identified types of rural education activities that could be most suitable for use of PV systems as a source of electricity. The purpose of this chapter is to characterize technical and economic appropriateness of PV systems when compared to practical alternatives currently being used in rural education facilities.

Technical feasibility of the applications is judged by the following criteria:

- Power Requirements. The study is primarily investigating applications that require less than 4 kWp of power. However, because several such common education applications require greater power levels, several applications will also be evaluated.

- Energy Use Profile. Since PV systems are capital-intensive, it would be preferable for them to operate on a base electrical load, as opposed to a peak or back-up mode. Thus, the applications being considered should involve a reasonably stable, year-round energy demand.

- Appropriate User Environment. Because stand-alone PV systems are being evaluated, the applications considered are located in unelectrified regions. They currently use, or plan to use, gasoline or diesel generators as a source of electricity. For some very small-scale applications, batteries are also considered an appropriate competitor. When these batteries have to be charged, they have to be taken to a town or village that is connected to a utility grid.

PV systems are judged not only on their technical appropriateness but also on their cost-competitiveness which is based on the comparison of PV systems' life-cycle cost to that of the competing conventional power system. Because the costs of PV systems are declining and conventional energy costs are increasing, at some point in time the costs become equal. PV systems are considered cost-competitive when the cost equality point is reached. The year in which costs become equal is termed the first year of cost-competitiveness. Because educational facilities are operated by both public and private-sector groups, economic and financial analyses, respectfully, are conducted to determine the cost-competitiveness of photovoltaic system application for both types of organizations.

The following generic educational applications are evaluated in this chapter:

- Cassette/radio for school
- Primary School
  - —audiovisual aids
  - —minimal facilities
  - —advanced facilities
- Secondary School
  - —minimal facilities
  - —advanced facilities
- Provincial College
  - —minimal facilities
  - —advanced facilities
- Adult Literacy Facilities
- Vocational Education Facilities
- Mobile Learning Centers

ORIGINAL PAGE IS OF POOR QUALITY

These applications encompass a wide variety of power requirements, ranging from 4.5 Wp to 32 kWp.

4.1 Applications Evaluation Methodology

ORIGINAL PAGE IS
OF POOR QUALITY

This section describes the procedure adopted in characterizing and selecting the electrical loads and energy use profiles used for the cost analyses.

4.1.1 Electrical Load and Energy Use Characterization

The United States Agency for International Development, the World Bank, private voluntary organizations, and the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) projects, discussed in Chapter 2, were examined to identify the electrical energy needs for each. Understandably, even within a single project type (e.g., primary school) the electrical needs vary between countries. Even within a country there are differences in power requirements within a project type. Thus, the load characterization is based on the needs of commonly used equipment. Thus, the applications are defined as "generic applications". For example, a primary school with minimal facilities will have lights for one classroom, administrative office, and a staff room, as well as audiovisual aids. The lights in the classroom are only for nighttime use. The primary school with advanced facilities will have two classrooms fully lit at night; four classrooms partially lit during the day; light for a staff room and office; audiovisual aids; calculator; transceiver; refrigerator; outdoor lighting, and a water pump.

The power requirements for the loads are based on equipment discussed in Chapter 3. Equipment usage is measured in terms of hours of use per day and days of use per year. Thus, annual energy requirements are equal to the product of equipment power requirements, hours of use per day and days of use per year. Total energy required for a facility equals the sum of energy required for each load. To account for electrical energy losses, total energy requirements are increased by twenty per cent. Because batteries are required for nighttime use, the percentage of energy used at night is also calculated. This aspect is used later in calculating battery capacity. Table 4.1 shows an example of a primary school with advanced facilities.

Once the local and energy use profiles were characterized, they were reviewed by education experts in various international organizations and, when needed, changes were made.

ORIGINAL PAGE IS
OF POOR QUALITY

4.1.2 System Sizing

Conventional gasoline or diesel generators for each application was sized by totalling the power needs of equipment that generally operates simultaneously. For applications requiring less than 1 kW of power a gasoline generator is used. Larger applications use diesel generators because they are most cost-effective at higher power levels. In the case of applications which have large numbers of motors, the generators are sized at about three times the operating loads of the motors. This sizing enables the generators to provide the required starting currents, without significant voltage drops.

The PV system is sized so that it can provide the annual energy needs, assuming an average solar insolation of 365 langleys per day. This insolation level is a typical average value in most countries between 30° north and south of the equator. At this level of insolation a 1kWp photovoltaic array will generate 1,600 kWp/year of electricity.* In calculating energy delivered to balance of system an efficiency of 90% was used. This accounts for losses due to array wiring, interconnections, derating etc. In addition, inorder to account for losses in the balance of system (leads, connection, DC/DC and DC/AC converters, batteries, distribution system etc.) it was assumed that 80% of power delivered to BOS was available to the load.

Batteries used with the PV array are designed to store adequate energy for five cloudy days and all nighttime energy needs. Only a ten per cent depth of discharge is allowed for providing nighttime energy needs. However, deeper (ninety per cent) discharge is allowed when cloudy periods occur. In the case in which a large number of motors are used, additional battery capacity is provided to accomodate high starting-current requirements.

* Rosenblum, L., W.J. Bifano, G.F. Hein and A.F. Ratajczak. Photovoltaic Power Systems for Developing Countries. NASA Technical Memorandum 79097 (Revised), January, 1980.

4.1.3 Cost Analyses

Once the PV and competing conventional energy systems are sized, life-cycle costs are computed for each. The cost components used are as follows:

- Installed PV system
  - —cost of the array and balance of system
  - —cost of batteries
  - —direct labor and spare parts cost for operation and maintenance
- Conventional energy systems
  - —cost for engine and generator
  - —fuel costs
  - —direct labor and spare parts cost for operation and maintenance

Cost analyses are based on accepted life-cycle costing principles. As mentioned previously, a life-cycle cost analysis was conducted with respect to both economic and financial factors. The economic life-cycle cost analysis measures the cost-competitiveness of PV systems from the national perspective. The financial analysis evaluates the competitiveness of PV systems from the perspective of an individual. The cost parameters used in each analysis are shown in Table 4.2. Life-cycle costs are computed for various years of installation between 1980 and 1990 for the PV and competing conventional energy system. The year in which life-cycle cost of the PV system becomes less than that of its competitor is the first year of cost-competitiveness of the PV system.

It should be noted that private educational facilities are often nonprofit, tax-exempt organizations. Thus, neither taxes nor depreciation are used in the financial analysis. Furthermore, the generic financial analyses assume that the cost of fuel to the consumer is higher than the opportunity cost of fuel used in the economic analysis. While this aspect holds true in most oil-importing developing countries, in countries, such as Mexico or Saudi Arabia, the reverse is true. However, because most AID projects are in poorer oil-importing countries, the assumptions shown in Table 4.2 are generally valid.

Because fuel costs are an important determinant of a PV system's cost-competitiveness and because escalation rates are uncertain, cost analyses are conducted for three fuel escalation rates.

4.2 Results from the Evaluation of Generic Applications

This section describes the type of equipment selected for the generic applications, their electrical load and energy profiles, and the competitiveness of PV systems, when compared to their nearest practical conventional alternative.

Table 4.3 shows the equipment used for each of the generic applications. Details of equipment and energy use profiles are shown in Tables A.1 through A.13 in Appendix A. Table 4.4 is a summary of the data in Appendix A and shows conventional power requirements, peak power requirements, battery capacity, and annual energy needs. Operating loads range from 20 W to 15 kW. Peak power requirements range from 4.5 Wp to 32kWp. Annual energy requirements range from 5 kWh/year to 45,456 kWh/year. These power and energy requirements will cover most stand-alone educational energy uses.

Table 4.5 shows the economic and financial cost-competitiveness of PV systems, as measured in terms of first year of cost-competitiveness, illustrating that, in general, under economic parameters PV systems will become cost-competitive prior to 1984, particularly if the conventional power source is operating at a low load factor. Financial parameters indicates that the year of cost-competitiveness is one year sooner. A fuel escalation rate of 0% tends to delay the year that cost-competitiveness is achieved by about one year, when compared to a 3% escalation rate. A fuel escalation rate of 6% tends to advance the year that cost competitiveness is achieved by about a year.

Applications requiring larger amounts of energy (e.g., vocational education or college facilities) reach cost-competitiveness after 1986. It should be noted that in the case of a mobile health center, even when energy needs are satisfied by batteries charged only when the truck is operating, a PV system can be competitive prior to 1984.

To summarize, cost-competitiveness of PV systems is enhanced by the following features:

- underutilization of conventional power systems;
- low battery storage requirements;
- competition with gasoline-powered generators; and
- low power requirements.

In general, PV systems will become cost-competitive prior to 1986 in most applications requiring less than 4 kW of power.

4.3 Comparison of Capital Costs of Generic Applications

An element of extreme importance in educational projects, particularly those sponsored by international aid organizations, is the capital required for a project. The aid organization may be responsible for building the facilities and equipping it. Local educational groups would be responsible for maintaining and operating the facility. Thus, in addition to evaluating projects based on technical and economic feasibility, aid organizations may evaluate projects of their capital requirements. An evaluation criterion such as "serve the greatest number of people per dollar of capital spent" will be a detriment to most PV projects.

Table 4.6 shows a comparison of capital costs of conventional and PV systems in the first year of cost-competitiveness. As expected, in most instances, the PV system's capital costs are substantially greater than that of the conventional power system. Only in applications where conventional power sources are underutilized are PV system costs comparable to its competitors. For example, a 300 W gasoline generator for operating audiovisual equipment in a school is only thirty per cent cheaper than a PV power source.

This aspect implies that financing schemes somewhat different from current practices will have to be employed if the criterion "serve the greatest number of people per dollar of capital spent" is to be satisfied by PV systems. For example, if a PV system is technically and economically feasible, an international aid organization could share the project's costs with its local counterparts. The local funds could be derived from the money that is saved because of the lower operating costs of the PV system. In this manner, the capital constraint could be overcome at a lower overall financing cost.

4.4 Sensitivity Analyses

In section 4.2, the effect of varying fuel escalation cost rates on the cost-competitiveness of PV systems was investigated. The analysis showed that reducing the escalation rate from 3% to 0% delayed cost-competitiveness by about a year. When the fuel escalation rate was increased from 3% to 6%, the year of cost-competitiveness was advanced by about a year. In this section, the sensitivity of cost-competitiveness to two other important variables is investigated. These two sets of analyses are the effect of holidays on cost-competitiveness and the effect of cost increases of a photovoltaic array on cost-competitiveness.

4.4.1 Effect of Holidays on Cost-Competitiveness

PV systems, like all other goods with high fixed costs, have to be used to their fullest extent to minimize the cost of use per unit. Thus, if electricity generated from a PV system is not used productively, cost per productive kilowatt-hour increases in proportion to the unused amount of electricity. This situation could occur in schools, when schools are closed for extended periods of time, such as holidays.

A sensitivity analysis was conducted for 500 Wp, 2 kWp, and 8kWp PV systems, assuming nonuse for periods of one, two, three, and four months. In general, a PV system unused for one month did not cause a delay in the year of cost-competitiveness. A two-month period of non-use causes a delay of one year. After that, every additional month that the PV system is unused, cost-competitiveness is delayed an additional year. Therefore, the following relationship appears to be true for the types of applications being evaluated in this study.

Delay in Year of Cost-Competitiveness = Months Unused - 1

Because the effect of wasting PV-generated electricity is significant, applications selected must be those which will use nearly all the electricity that is generated. For example, in the case of a primary school, the electrical base load could be met by an adult literacy program which operates year-round. Thus, closing the primary school for a month would not greatly affect cost-competitiveness.

4.4.2 Effect of Increased PV Costs

The previous analyses were based on PV array cost projections made by the Jet Propulsion Laboratory (Table 4.2). The projected decline in array costs are based on attaining certain levels of production, the use of new production technologies and the development of more efficient materials. There is a possibility that the target cost reductions may not materialize in the anticipated time frame. The purpose of this section is to investigate the effect of higher array costs on the cost-competitiveness of the PV system.

The procedure adopted is to calculate the delay in the year of cost-competitiveness caused by a ten and twenty per cent increase in PV array costs. Table 4.7 shows the results of this sensitivity analysis. In general, a ten per cent cost increase does not significantly delay the year of cost-competitiveness. A twenty per cent cost increase causes the PV system to be competitive one to two years later. However, for applications already competitive a twenty per cent increase does not cause any delay in the year of cost competitiveness.

4.5 Conclusions

Thirteen generic educational applications were evaluated to test the economic and technical feasibility of using PV electricity. All applications requiring less than about 2 kWp of power were found to compete favorably with conventional alternatives on or before 1984. Applications requiring about 2—8 kWp of power are competitive with conventional alternatives in the 1984—1986 time frame. Applications requiring larger arrays became cost-competitive only after 1986. From the viewpoint of demonstration project timing, the feability of applications, such as primary and secondary schools, adult literacy facilities, and mobile health centers, could be demonstrated in the 1980-1986 time frame.

Inasmuch as the foregoing were generic analyses, prior to recommending a demonstrated project, a technical and cost analysis should be conducted for a specific country. This analysis should reflect actual conditions in the country and should use the most current PV system cost estimates available.

TABLE 4.1

SAMPLE APPLICATION: PRIMARY SCHOOL - ADVANCED - 120 STUDENTS

Number	Description	Power W	Hrs/Day	Usage Days/Yr.	%Night	Energy Required Kwh Night	Total
Classrooms (4)							
28	Florescent lights (2 rooms)	40	2	260	100	582	582
16	Florescent lights (4 rooms)	40	6	260	-	-	998
1	Radio/cassette	15	3	260	-	-	12
1	Filmstrip Projector	200	0.2	100	50	2	4
Office (1)							
6	Florescent lights	40	8	260	25	125	499
1	Calculator	17	2	260	-	-	9
1	Transceiver	36	0.5	200	10	-	4
Staff Room (1)							
3	Florescent light	40	8	260	25	62	250
1	Refrigerator	40	12	365	50	88	175
Outdoor Lighting							
2 Florescent lights		40	4	365	100	117	117
Water Pump							
20 liters per capita day(lcd) 120 persons/10m head		40	4	260	-	-	42
Power Required		2KW					
	Energy Required					976	2692
	Losses 20%					195	538
	Total Energy Required					1171	3230

Average Night Use = 36%

ORIGINAL PAGE IS OF POOR QUALITY

TABLE 4.2

PARAMETERS USED IN COST ANALYSES

	Economic Analysis	Financial Analysis
Interest Rate (Percent)	12	23
Discount Rate (Percent)	12	23
Inflation Rate (Percent)	-	10
Fuel Escalation Rates (Percent)	0,3#,6	10,13.3,16.6
Analysis Life (Years)	20	20
Battery Life (Years)	5	5
Fraction of initial investment borrowed	-	0.9
Generator Costs (1980 dollars)		
300 W gasoline	320	320
1.2KW gasoline	530	530
4KW diesel	4000	4000
6KW diesel	4500	4500
20KW diesel	9000	9000
45KW diesel	17000	17000
Battery cost (12V, 936 amp-hours)	500	500
Fuel Costs (12V, 221 amp-hours)	230	230
(6V, 10 amp-hours)	20	20
(12V, 105 amp-hours)	150	150
Gasoline ($/gallon)	1.25	1.75
Diesel ($/gallon)	1.10	1.50
PV Array costs (1980 $/KWp)		
1980	17170	17170
1982	8050	8050
1984	5960	5960
1986	3870	3870
1988	3000	3000
1990	2800	2800
Average Insolation (Langleys/day)	376	376

Based case assumption.

NOTE: A discount rate of 23 percent is equivalent to a real discount rate of 12 percent when inflation rate is 10 percent per annum. Similarly fuel escalation rates of 10, 13.3 and 16.6 percent are equivalent to real escalation rates of 0,3 and 6 percent when inflation rate is 10 percent. PV array costs are based on JPL cost projections (JPL-Draft Program Summary Document, Pasadena, California, 1980).

TABLE 4.3 EQUIPMENT USED IN GENERAL APPLICATIONS

APPLICATION	ELECTRICALLY POWERED EQUIPMENT USED
Audio aid for school	Cassette tape recorder/radio
Primary School	
- Audio visual aids	Cassette tape recorder/radio, slide/film projector and TV
- Minimal Facilities	Lights for classroom, administrative office and staff room; and audio visual aids as above
- Advanced Facilities	As above plus outdoor lighting, calculator transceiver, refrigerator and water pump.
Secondary School	
- Minimal Facilities	Lights for science laboratory, administrative office and library; TV, cassette/radio slide/film, strip projector, sound amplifier
- Advanced Facilities	As above plus lights for classroom, community hall and corridors.
Adult literacy Facility	Lights for classroom, cassette tape recorder/radio, and slide/film strip projector and TV.
Vocational Education Facility	Metal working shop--lights, power hacksaw, metal band saw, lathe, milling machine & drill press, spot welder, arc welder, air compressor, grider. Wood working shop--lights, radial arm saw, vertical band saw, wood lathe, drills, circular saw, and TV, radio/cassette and slide projector and lights for office.
College	
- Minimal Facilities	Lights for dormatories, library, kitchen, dining room, laboratory, offices, workshop and calculators, typewriters, TV, film projector, workshop equipment
- Advanced Facilities	Same as above plus lights for classroom and two laboratories.
Mobile Health Center	Cassette tape/radio, film strip/slide projector, refrigerator, lights. All are on a truck.

TABLE 4.4

POWER AND ENERGY REQUIREMENTS FOR APPLICATIONS

APPLICATION	CONVENTIONAL POWER SYSTEM			PV SYSTEM		ANNUAL ENERGY REQUIREMENTS Kwh
	RATED POWER KW	OPERATING KW	FUEL	ARRAY CAPACITY KWp	BATTERY CAPACITY AH	
• Battery Charger-tape/radio for schools			*			
(a) competing against battery	12V 221 AH		battery	0.0045	20	5
(b) Competing against gasoline generator	0.3	0.02	gasoline	0.0045	20	5
• Primary School						
- audio-visual equipment only	0.3	0.03	gasoline	0.02	105	25
- minimal facilities	1.2	0.7	gasoline	0.47	1872	674
- advanced facilities	4.0	2.0	diesel	2.25	6552	3230
• Adult Literacy Facilities	0.8	0.6	gasoline	0.40	2808	570
• Secondary School						
- minimal facilities	4.0	2.0	diesel	2.18	4680	3116
- advanced facilities	6.0	4.0	diesel	4.14	7488	5936
• Vocational Education	45.0	10.0	diesel	8.56	21528	12263
• College						
-Minimal Facilities	6.0	4.0	diesel	10.82	39312	15245
-Advanced Facilities	20.0	15.0	diesel	31.73	73008	45456
• Mobile Health Center	135	0.07#	diesel	0.14	663	196

*Battery is taken into an electrified town or village for recharging.
#Run off truck engine.

TABLE 4.5

COST-COMPETITIVENESS OF PV SYSTEMS

APPLICATION	Conventional Energy Power Requirement KW	PV Power Requirement KWp	Fuel Escalation 0% Economic Analysis	Fuel Escalation 0% Financial Analysis	Fuel Escalation 3% Economic Analysis	Fuel Escalation 3% Financial Analysis	Fuel Escalation 6% Economic Analysis	Fuel Escalation 6% Financial Analysis
• Battery Charger-tape/radio for schools (a) competing against battery	12V 221AH	0.0045	1980	1980	1980	1980	1980	1980
(b) competing against gasoline generator	0.3 (gas)	0.0045	1980	1980	1980	1980	1980	1980
• Primary School - audio-visual equipment only	0.03 (gas)	0.02	1980	1980	1980	1980	1980	1980
- minimal facilities	0.7 (gas)	0.47	1984	1982	1983	1982	1982	1981
- advanced facilities	2. (diesel)	2.25	1984	1983	1983	1982	1982	1982
• Adult Literacy Facilities	0.6 (gas)	0.40	1986	1984	1984	1982	1982	1982
• Secondary School - minimal facilities	2 (diesel)	2.18	1983	1982	1982	1982	1982	1982
- advanced facilities	4 (diesel)	4.14	1986	1986	1986	1985	1985	1984
• Vocational Education	10 (diesel)	8.56	1988	1987	1986	1986	1985	1984
• College - minimal facilities	4	10.82	1990	1990	1988	1986	1986	1985
- advanced facilities	15 (diesel)	31.73	1990	1990	1990	1990	1989	1988
• Mobile Health Center - truck engine run for charging battery	0.07 (diesel)	0.14	1980	1980	1980	1980	1980	1980
- battery charged only when truck is running	0.07 (diesel)	0.14	1984	1983	1983	1983	1982	1982

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 4.6

COMPARISON OF CAPITAL COSTS IN THE FIRST YEAR OF ECONOMIC COST-COMPETITIVENESS AT A 3% FUEL COST ESCALATION RATE

APPLICATION	INITIAL CAPITAL COSTS (1980 Dollars)		RATIO CONVENTIONAL SYSTEM COST TO PV SYSTEM COST
	CONVENTIONAL SYSTEM	PV SYSTEM	
● Battery Charger - tape/radio for schools			
(a) competing against gasoline generator	230	117	2.7
(b) competing against gasoline generator	320	117	2.7
● Primary School			
- audio-visual equip. only	320	350	0.71
- minimal facilities	580	4292	0.14
- advanced facilities	5600	19331	0.29
● Adult Literacy Facilities	520	3048	0.17
● Secondary School			
- minimal facilities	5600	20049	0.28
- advanced facilities	6300	24348	0.25
● Vocational Education	23800	44627	0.53
● College			
- minimal facilities	6300*	53460	0.12
- advanced facilities	NC	NC	NC
● Mobile Health Center	560	2404	0.23

*Not competitive

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 4.7

DELAY IN YEAR OF ECONOMIC COST-COMPETITIVENESS WITH HIGH PV ARRAY COSTS*

APPLICATIONS	FIRST YEAR OF COST-COMP. IN BASE CASE	DELAY IN YEAR OF COST-COMPETITIVENESS (Years) FOR ARRAY COST INCREASE OF: 10%	20%
• Battery Charger-tape/radio for schools			
(a) competing against battery	1980	0	0
(b) competing against gasoline generator	1980	0	0
• Primary School			
- audio-visual equipment only	1980	0	0
- minimal facilities	1983	0	1
- advanced facilities	1983	0	1
• Adult Literacy Facilities	1984	0	1
• Secondary School			
- minimal facilities	1982	1	2
- advanced facilities	1986	0	0
• Vocational Education	1986	0	1
• College			
- minimal facilities	1988	1	2
- advanced facilities	1990	0	0
• Mobile Health Center			
- truck engine run for battery charging	1980	0	0
- battery charged only when truck is operated.	1983	0	1

*Based on economic analysis with a 3% fuel escalation rate.

5.0 THE POTENTIAL FOR PV DEMONSTRATION PROJECTS IN RURAL EDUCATION

5.1 Summary

Previous chapters in this report have summarized electrical equipment currently used in educational facilities, ongoing and future AID education projects and have analyzed both the technical and economic viability of generic educational facilities. Based on this information, those AID education projects that appear to be prime candidates for PV demonstrations are able to selected. As a cautionary note, it should be expressed that much of the data gathered on education projects and equipment load profiles are subjective, being based on interviews with AID and PVO experts in education. Although the data are subjective, the reiterative process of interviews and literature searches that the DHR/ARD team undertook during the period of performance of this contract has greatly increased the accuracy of the gathered data. The reader, however, must not substitute these data for actual in-country examination of all projects selected for demonstrations.

The criteria used in selecting education projects included:

- Remoteness;
- Visibility;
- Insolation;
- Relationship to AID's program direction and needs;
- Value of a demonstration project's being replicated;
- Technical viability; and
- Economic viability.

Those projects were selected from the projects defined in Tables 2.3 and 2.4 that appeared to be good or excellent in terms of remoteness, visibility, insolation, and replicability, etc. In addition, those PV facilities are discarded that do not appear to be economically viable by 1985 (based on economic analysis and assuming a 0% fuel escalation rate). Such facilities include vocational educational projects, adult literacy, advanced secondary schools, and provincial colleges with minimal and advanced facilities. The remaining projects appear to meet the above-defined criteria and can be considered for further analysis. These projects are summarized in Table 5.1.

One problem encountered in the selection of appropriate education projects for possible PV demonstrations is that AID-sponsored education projects usually

include more than one school site. For example, a rural primary education project may fund up to forty primary schools throughout a particular country. Therefore, a decision must be made. Should one school or several schools within a project be equipped with PV power systems? Based on the criterion of visibility, it may be best to select several schools within a project, however, such selection will increase costs of any demonstration projects.

In selecting projects for PV demonstration systems, an assumption was made in this analysis that those PV systems that would be economically viable by 1985 would attract the attention of local government officials and entrepreneurs. Considering that the lead time between developing a demonstration project and the first substantial influx of investors is three to four years, then educators, AID projects officers, etc., who would want to include PV in education projects can do so now with the knowledge that they are cost-effective.

5.2 Findings

Generally, educational facilities less than 4 kWp in size can be considered for PV demonstrations. This finding does depend on the annual energy requirements, financial parameters used in the analysis, prevailing energy and conventional energy system costs. As a rule of thumb, primary schools, primary schools with adult literacy programs, minimal facility secondary schools and mobile educational centers are good prospects for PV systems today. In fact, many schools can be economically outfitted today with PV systems in place of gasoline and diesel generating sets.

Of the projects identified for PV demonstrations, twenty-six are in Latin America, seven in Africa, and seven in Asia. Of these projects selected, forty have a primary school component, twenty-two a secondary school component, and two have mobile education centers. These projects are representative of the present direction of USAID educational activities. As mentioned previously, each project may have a broad scope, including primary, secondary, as well as general administrative components. This aspect implies that each project must be broken down into its constituent parts for further analysis before a demonstration project is selected.

TABLE 5.1

EDUCATION PROJECTS HAVING HIGH POTENTIAL FOR DEMONSTRATION OF PHOTOVOLTAIC SYSTEMS

[ONGOING EDUCATION PROJECTS]

COUNTRY	PRIMARY SCHOOL— IMPROVED FACILITIES	PRIMARY SCHOOL— MINIMAL FACILITIES	SECONDARY SCHOOL— MINIMAL FACILITIES	MOBILE CENTER	AID PROJECT TITLE
EL SALVADOR	2	2			RURAL PRIMARY SCHOOL EXPANSION
GUATEMALA	2	2			EDUCATION AND HUMAN RESOURCES DEVELOPMENT
DEVELOPMENT SUPPORT	2	2	2		RURAL SATELLITE PROJECT-DEVELOPMENT COMMUNITY
EL SALVADOR	2				EL SALVADOR EDUCATIONAL DEVELOPMENT
EL SALVADOR	2				EDUCATION REFORM PROGRAM
GUATEMALA	1	1			PRIMARY SCHOOL IMPROVEMENT
JAMAICA	2	2	2		RURAL SECTOR EDUCATION LOAN
KOREA	2	2	2		MIDDLE SCHOOL PILOT PROJECT
NICARAGUA	2				RURAL EDUCATION DEVELOPMENT
NEAR EAST REGIONAL	2	2	2		CRS WEST BANK—RURAL DEVELOPMENT II—EDUCATION
LESOTHO	2	2	2		INSTRUCTIONAL MATERIALS RESOURCE CENTER
PARAGUAY	1	1	1		BILINGUAL EDUCATION
PERU	2	2	2		EDUCATION FOR RESPONSIBLE PARENTHOOD
PERU	1				EDUCATION SERVICE CENTERS
SUDAN	2	2	2		RURAL HEALTH SUPPORT
ZAIRE	2	2	2		MATERNAL/CHILD HEALTH/FAMILY PLANNING
GUATEMALA	1	1	1		BASIC RURAL EDUCATION
HONDURAS	2	2	2		CIVIC DEVELOPMENT (LEADERSHIP TRAINING)
HONDURAS	2	2			RURAL EDUCATION
INDONESIA	1				EDUCATION COMMUNICATIONS DEVELOPMENT
BOLIVIA				2	MOBILE HEALTH PROGRAM
COSTA RICA	2	2	2		NUTRITION PROGRAM
COSTA RICA	2	2	2		FAMILY PLANNING SERVICES
HONDURAS	2	2			HONDURAS NUTRITION
NICARAGUA	2	2	2		NICARAGUA—RURAL COMMUNITY HEALTH SERVICES
PAKISTAN	2			2	SUPPORT OF FAMILY PLANNING ASSOCIATION ACTIVITIES
PANAMA	1	1			POPULATION II (PANAMA)
PERU	1				NONFORMAL EDUCATION
TANZANIA	1				VOCATIONALIZATION OF PRIMARY SCHOOLS
LATIN AMERICA REGIONAL	2	2	2		RURAL COMMUNICATIONS SERVICES
PANAMA	2	2	2		NONFORMAL EDUCATION (PLAN GUAYMI)
PARAGUAY	2				RURAL RADIO EDUCATION
THAILAND	2				RURAL EDUCATION
NEPAL	1	1			RADIO EDUCATION TEACHER TRAINING
CHAD	1				COMPREHENSIVE HUMAN RESOURCES DEVELOPMENT
INDONESIA			2		NONFORMAL EDUCATION

KEY: 1—EXCELLENT; 2—GOOD

TABLE 5.1

EDUCATION PROJECTS HAVING HIGH POTENTIAL FOR DEMONSTRATION OF PHOTOVOLTAIC SYSTEMS

COUNTRY	PRIMARY SCHOOL— ADVANCED FACILITIES	PRIMARY SCHOOL— MINIMAL FACILITIES	SECONDARY SCHOOL— MINIMAL FACILITIES	MOBILE CENTER	[FUTURE EDUCATION PROJECTS] AID PROJECT TITLE
NICARAGUA	1	1	1		EDUCATION SECTOR PROGRAM
CENTRALLY FUNDED	2	2	2		TEACHING SCIENCE BY RADIO
PERU	1	1	1		SOUTHERN SIERRA EDUCATION SECTOR
MAURITANIA			1		AGRICULTURE AND HUMAN RESOURCES DEVELOPMENT
YEMEN ARAB REPUBLIC	2	2	2		BASIC EDUCATION DEVELOPMENT
ZIMBABWE	2				EDUCATION AND MANPOWER DEVELOPMENT

APPENDIX A - LOAD AND ENERGY USE PROFILES FOR GENERIC APPLICATIONS

Number	Description	POWER W	Usage hrs/day	Usage days/yr.	Usage %night	Energy Required KWh/yr. Night	Energy Required KWh/yr. Total
1	Tape/radio	16	1	260	-	-	4.27

Energy Required	4.27
Losses 20%	.85
Total Energy Required	5.12

% Average Night Use = 0

APPLICATION: Primary School - Audio Visual Equipment

			Usage			Energy Required KWh/yr.	
Number	Description	POWER W	hrs/day	days/yr.	%night	Night	Total
1	Cassette/Radio	15	1	260	-	-	4
1	Slide/Film Strip Projector	16	1	260	-	-	4
1	TV	50	1	260	-	-	13

Energy Required	21
Losses 20%	4
Total Energy Required	25

% Average Night Use = 0

APPLICATION: Primary School--Minimal--120 students & night school
3 multigrade classroom, one lighted for night use.

Number	Description	POWER W	Usage hrs/day	days/yr.	%night	Energy Required KWh/yr. Night	Total
14	Fluorescent lights 3000 lm/classroom	40	2	260	100	291	291
2	lights for admin. use	40	6	260	30	37	125
2	lights for staff room	40	6	260	30	37	125
1	cassette/radio	15	1	260	-	-	4
1	slide/film strip projector	16	1	260	-	-	4
1	TV	50	1	260	-	-	13
	Energy Required					365	562
	Losses 20%					73	112
	Total Energy Required					438	674

% Average Night Use = 65

APPLICATION: PRIMARY SCHOOL - ADVANCED - 120 STUDENTS

Number	Description	Power W	Usage Hrs/Day	Usage Days/Yr.	%Night	Energy Required Kwh Night	Energy Required Kwh Total
Classrooms (4)							
28	Florescent lights (2 rooms)	40	2	260	100	582	582
16	Florescent lights (4 rooms)	40	6	260	-	-	998
1	Radio/cassette	15	3	260	-	-	12
1	Filmstrip Projector	200	0.2	100	50	2	4
Office (1)							
6	Florescent lights	40	8	260	25	125	499
1	Calculator	17	2	260	-	-	9
1	Transceiver	36	0.5	200	10	-	4
Staff Room (1)							
3	Florescent light	40	8	260	25	62	250
1	Refrigerator	40	12	365	50	88	175
Outdoor Lighting							
2	Florescent lights	40	4	365	100	117	117
Water Pump							
	20 liters per capita day(lcd) 120 persons/10m head	40	4	260	-	-	42
Power Required		2KW					
	Energy Required					976	2692
	Losses 20%					195	538
	Total Energy Required					1171	3230

Average Night Use = 36%

APPLICATION: Adult Literacy - One Classroom lighted for 40 students

Number	Description	POWER W	Usage hrs/day	days/yr.	%night	Energy Required KWh/yr. Night	Total
14	Fluorescent lights	40	3	260	100	437	437
1	Cassette/Radio	15	1	260	100	4	4
1	Slide/Film Strip Projector	16	2	260	100	8	8
1	TV	50	2	260	100	26	26

Competing against and 800W gasoline generator operating at 600W average load.

	Night	Total
Energy Required	475	475
Losses 20%	95	95
Total Energy Required	570	570

% Average Night Use = 100

APPLICATION: Secondary School--Minimal - 600 students

Number	Description	POWER W	Usage hrs/day	Usage days/yr.	Usage %night	Energy Required KWh/yr. Night	Energy Required KWh/yr. Total
Science Laboratory							
10	Fluorescent lights	40	2	100	-	-	80
1	Refrigerator	100	12	365	50	219	438
2	Fans	200	4	100	-	-	160
Administrative Offices							
6	Fluorescent lights	40	6	260	-	-	500
Library							
14	Fluorescent lights	40	8	300	-	-	1344
1	TV	50	1	260	-	-	39
1	Radio	5	4	260	-	-	5
Community Hall							
1	Slide/Film Projector	600	1	50	-	-	30
1	Amplifier	20	1	50	-	-	1

Using a 4KW diesel operating at 2KWc

	Night	Total
Energy Required	219	2597
Losses 20%	44	519
Total Energy Required	263	3116

% Average Night Use = 8

APPLICATION: Secondary School - Advanced - (No night school)

Number	Description	POWER W	Usage hrs/day	Usage days/yr.	Usage %night	Energy Required KWh/yr. Night	Energy Required KWh/yr. Total
Classrooms (15)							
30	Fluorescent lights	40	5	260	-	-	1560
Science Laboratory							
10	Fluorescent lights	40	2	100	-	-	80
1	Refrigerator	100	12	365	50	219	438
2	Fans	200	4	100	-	-	160
Staff Room							
6	Fluorescent lights	40	6	260	-	-	374
1	Radio	2	3	260	-	-	2
Administrative Offices (2)							
6	Fluorescent lights	40	8	260	-	-	500
Library							
14	Fluorescent lights	40	8	300	-	-	1344
1	TV	50	3	260	-	-	39
1	Radio	5	4	260	-	-	5
Community Hall							
20	Fluorescent lights	40	1	50	-	-	40
1	Slide/Film Projector	600	1	50	-	-	30
1	Amplifier	20	1	50	-	-	1
Corridor Lights							
6	Fluorescent lights	40	6	260	-	-	374
Energy (6KWc) Required						219	4947
Losses 20%						44	989
Total Energy Required						263	5936

% Average Night Use = 4

APPLICATION: Vocational Training--Metal & Woodworking School

Number	Description	POWER W	Usage hrs/day	days/yr.	%night	Energy Required KWh/yr. Night	Total
Metal Working Shop							
1	Power Hacksaw	250	1	260	0	0	65
1	Metal band saw	375	1	260	0	0	98
1	Lathe	5200	2	260	0	0	2704
1	Milling Machine/ Drill press	1200	1	260	0	0	312
1	Drill Press	375	4	260	0	0	390
1	Spot Welder	1500	1	260	0	0	390
1	Arc Welder	3000	1	260	0	0	780
1	Air Compressor	1500	4	260	0	0	1560
1	Grinder	375	4	260	0	0	390
Wood Working Shop							
1	Radial arm saw	1500	1	260	0	0	390
1	Vert. band saw	375	2	260	0	0	195
1	Wood lathe	400	1	260	0	0	104
2	Drills	250	3	260	0	0	390
1	Circular saw	1200	3	260	0	0	936
24	Fluorescent lights	40	6	260	0	0	1500
1	TV	50	0.5	260	0	0	7
1	Radio/cassette	10	0.5	260	0	0	1
1	Slide Project	50	0.5	260	0	0	7

Energy Required		10219
Losses 20%		2044
Total Energy Required	0	12263
% Average Night Use = 0		

ORIGINAL PAGE IS OF POOR QUALITY

APPLICATION: Provincial College - Minimal - 3000 students, 30 classrooms

Number	Description	POWER W	Usage hrs/day	days/yr.	%night	Energy Required KWh/yr. Night	Total
30 Classrooms							
2 Science Laboratories							
28	Fluorescent lights	40	6	260	-	-	1747
2	Refrigerator	50	12	365	50	219	438
4	Fans	100	6	260	-	-	624
Workshop							
2	Drills	250	1	260	-	-	130
8	Fluorescent lights	40	8	260	-	-	666
1	Circular Saw	500	1	260	-	-	130
1	Band Saw	500	1	260	-	-	130
Dormitory 60 Students, 30 rooms							
30	Fluorescent lights	40	6	365	100	2628	2628
Library							
30	Fluorescent lights	40	8	260	-	-	2496
1	TV	50	2	260	-	-	26
1	Projector	200	1	100	-	-	20
2	toilets						
12	Fluorescent lights	40	4	365	100	701	701
1	Dining Room						
30	Fluorescent lights	40	2	365	100	876	876
1	Kitchen						
10	Fluorescent lights	40	4	365	100	584	584
Accounting Department							
10	Fluorescent lights	40	8	260	-	-	832
2	Calculators	15	4	260	-	-	31
2	Typewriters	100	4	260	-	-	208
Presidents Office							
4	Fluorescent lights	40	8	260	-	-	333
-1	Typewriter	100	4	260	-	-	104

Conventional System - 6KW operating at 4 KWc

	Night	Total
Energy Required	5008	12704
Losses 20%	1002	2541
Total Energy Required	6010	15245

% Average Night Use = 40

ORIGINAL PAGE IS
OF POOR QUALITY

APPLICATION: Provincial College -Advanced - 3000 students, 30 classrooms

Number	Description	POWER W	Usage hrs/day	Usage days/yr.	Usage %night	Energy Required KWh/yr. Night	Energy Required KWh/yr. Total
30 Classrooms							
300	Florescent lights	40	8	260	-	-	24960
2 Science Laboratories							
28	Florescent lights	40	6	260	-	-	1747
2	Refrigerator	50	12	365	50	219	438
4	Fans	100	6	260	-	-	624
4	Misc.	50	6	260	-	-	78
Workshop							
2	Drills	250	1	260	-	-	130
8	Florescent lights	40	8	260	-	-	666
1	Circular saw	500	1	260	-	-	130
1	Bard Saw	500	1	260	-	-	130
1	Misc.	50	4	260	-	-	52
Dormitory 60 Students, 30 rooms							
60	Florescent lights	40	6	365	100	5256	5256
2 Toilets							
12	Florescent lights	40	4	365	100	701	701
1 Dining Room							
30	Forescent lights	40	2	365	100	876	876
1 Kitchen							
10	Florescent lights	40	4	365	100	584	584
Accounting Department							
10	Florescent lights	40	8	260	-	-	832
2	Calculators	15	4	260	-	-	31
2	Typewriters	100	4	260	-	-	208
Presidents Office							
4	Florescent lights	40	8	260	-	-	333
1	Typewriter	100	4	260	-	-	104

Conventional System-20KW operating at 15KWc

	Night	Total
Energy Required	7636	37880
Losses 20%	1527	7576
Total Energy Required	9163	45456
% Average night use = 20		

APPLICATION: Mobile Health Center

Number	Description	POWER W	Usage hrs/day	Usage days/yr.	Usage %night	Energy Required KWh/yr. Night	Energy Required KWh/yr. Total
1	Tape/Radio	15	3	365	50	8	16
1	Film Strip Projector	40	1	365	50	8	15
1	Refrigerator	-	12	365	50	44	88
1	Fluorescent light	40	3	365	100	44	44

Power required = 0.07KW

Conventional Power Unit

Operates off truck engine and engine runs separately at almost idling = 1.4 gallon/hr. and $100 incremental cost for larger alternator

Battery costs = $460 every five years.

	Night	Total
Energy Required	104	163
Losses 20%	21	33
Total Energy Required	125	196

% Average Night Use = 64

ORIGINAL PAGE IS
OF POOR QUALITY